EXPLORING WHETHER IT IS POSSIBLE TO CONSIDER LANDINGS OF ANY OF THE *NEPHROPS* FUNCTIONAL UNITS 25, 31, 26-27 AS BYCATCH OF SOME FLEETS AND SPECIES

Esther Abad and Carmen Fernández
Instituto Español de Oceanografía

Nephrops in ICES Division VIIIc consists of 2 functional units (FUs): 25 (North Galicia) and 31 (Cantabrian Sea), which are both assessed by ICES to be at very low levels. For these FUs, ICES has been recommending zero catch since 2002.

The situation is similar for FUs 26-27 (West Galicia and North Portugal), in ICES Division IXa, for which ICES recommendation has been zero catch since 2003.

Landings in all these FUs have been very low for about one decade. Discards are believed to be minimal (only soft or damaged individuals are discarded).

FUs 25 and 26-27 were last assessed using an analytical procedure (XSA, after applying slicing to the length frequency distributions of the landings) in WGHMM 2006, with the results being considered only indicative of stock trends. At that time, landings of FU 31 were already considered too low to conduct an analytical assessment of this FU. Since then, landings have been so low in all FUs that no further analytical assessment has been attempted and their status has been assessed by examination of trends in landings, commercial LPUE and mean size in the landings.

FUs 25 and 31 are exploited exclusively by the Spanish bottom trawl fleet operating in ICES Division VIIIc, whereas FU 26-27 are exploited mostly by the Spanish bottom trawl fleet operating in ICES Division IXa (North) and, to a much lesser extent, by Portuguese trawl and artisanal fleets operating in the same area.

The Spanish bottom trawl fleet operates a mixed fishery in VIIIc and IXa (North), catching a variety of species, mainly hake, anglerfish, megrim and horse mackerel. *Nephrops* can no longer be considered a target species of this fleet and, as already indicated, *Nephrops* landings have been very low for about 1 decade.

In this work we examine whether, for the Spanish bottom trawl fleet in VIIIc and IXa (North), a relationship can be found between landings of *Nephrops* and landings of either hake or anglerfish (the other species to be considered in the requested HCRs), which could allow us to get an estimate of *Nephrops* future landings from projections of landings of these other species. In principle, it is expected that a relationship with anglerfish could be more likely than with hake. The reason is that this bottom trawl fleet operates with two different gears (often within the same trip) and one of the gears catches mostly hake and horse mackerel, whereas the other one catches mostly hake, anglerfish, megrim and *Nephrops*. Hence, *Nephrops* catches are expected to be more closely associated with anglerfish than with hake catches.

Figure 1 displays time series of landings of FU25, 26-27 and 31 (top left panel), white anglerfish (*Lophius piscatorius*, labelled as "P") landed by Spanish bottom trawl in VIIIc, IXa and VIIIc-IXa together (top right panel), black anglerfish (*Lophius budegassa*, labelled as "B") landed by Spanish bottom trawl in VIIIc, IXa and VIIIc-IXa together (bottom left panel) and hake (labelled as "H") landed by Spanish bottom trawl in VIIIc-IXa together (bottom right panel). The data come from the WGHMM 2010 report.

Figure 2 displays pairwise scatterplots of these same time series, to try and see whether a relationship can be visually seen between landings of these *Nephrops* FUs and landings of P, B or H. Over the whole time series, it seems that there is some positive association between landings of Nephrops and landings of anglerfish (P, for *piscatorius*, or B, for *budegassa*).

The potential association between landings of *Nephrops* and landings of anglerfish is examined in more detail in Figure 3 (for a possible association with P), Figure 4 (for a possible association with B) and Figure 5 (for a possible association with both species of anglerfish, PB). Scatterplots are again presented, with a line linking the points through time. The least squares fit is also displayed in these figures (linear fit results are attached in Annex at the end of this document). The last years are always the ones of low *Nephrops* catch. The overall conclusion from these figures is that, although there seems to be some positive association between landings of *Nephrops* and landings of anglerfish when the whole time series is considered (because, essentially, landings have decreased substantially for *Nephrops* and for anglerfish over the range of years analysed), this does not hold in the last 8-10 years, when *Nephrops* landings have been extremely low and do not seem to be associated with anglerfish landings.

Hence, it does not seem possible to forecast *Nephrops* landings from landings of hake or anglerfish.

Clearly, landings depend on effort, catchability and stock abundance. It might be expected that fishing effort is more or less similar for *Nephrops* and anglerfish, but the same will not necessarily hold for catchability and/or stock abundance trends. Therefore, it is not surprising to find that *Nephrops* landings can not be predicted from anglerfish landings.

We also examined whether the estimated F trends for *Nephrops* (taken from the assessments conducted by WGHMM 2006) might be related to the partial F estimated for either P or B, for the Spanish bottom trawl fleet in VIIIc, in IXa (North) and in VIIIc-IXa together. To compute the partial Fs for P and B, the estimated total stock F (taken from WGHMM 2010 report) was multiplied by the proportion of the species landings coming from these fleets (landings data, also from WGHMM 2010 report).

Time series of F trends are displayed in Figure 6 (no reference to absolute values on the vertical axes should be paid, it should only be viewed in relative terms), with scatterplots of these time series presented in Figure 7. No relationship can be appreciated between the estimated trends in F for *Nephrops* and for anglerfish.

As a final comment, we point out the marked seasonal character of the *Nephrops* landings. Figure 8 displays the monthly proportions of the Spanish bottom trawl fleet annual landings for FUs 25, 26-27 and 31 combined. It is clear from the figure that the majority of landings occur between May and August and this seasonal pattern is stable through the years.

Conclusions:

It does not seem possible to forecast *Nephrops* landings from hake or anglerfish landings, and neither do the trends in estimated F for these species appear to be related.

Given the very low biomass level of *Nephrops* FUs 25, 26-27 and 31, the catch of these FUs should remain as low as possible, but the mixed nature of the Spanish bottom trawl fishery, for which *Nephrops* is no longer a target species, makes this difficult to accomplish. Nonetheless, measures taken to reduce F for hake (for which current F is estimated to be 3 times above Fmsy) and anglerfish (*L. piscatorius* currently about 1.5 times above Fmsy) should have the effect of also reducing fishing pressure on *Nephrops*. The strong seasonality of the *Nephrops* fishery, with most of the landings between May and August, should be taken into account when devising management measures, ensuring that any measures applied to reduce effort also include these months.

FIGURE 1: Time series of landings of Nephrops (top left), *L. piscatorius* (top right), *L. budegassa* (bottom left) and hake (bottom right), by the Spanish bottom trawl fleet operating in Div. VIIIc, IXa (North) and VIIIc+IXaN together

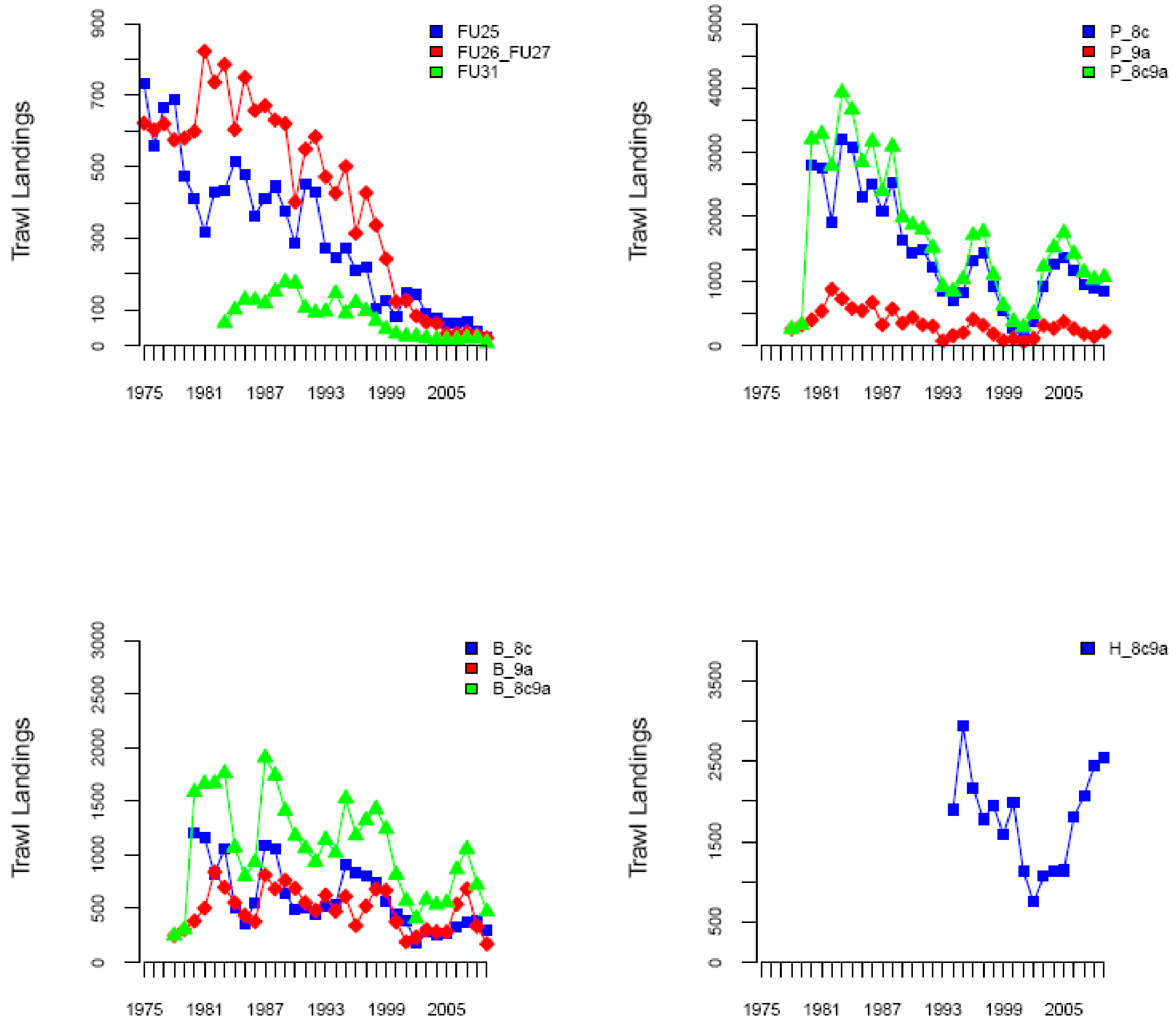


FIGURE 2: Scatterplots of landings of Nephrops, *L. piscatorius* (P), *L. budegassa* (B) and hake (H), by the Spanish bottom trawl fleet operating in Div. VIIIc, IXa (North) and VIIIc+IXaN together

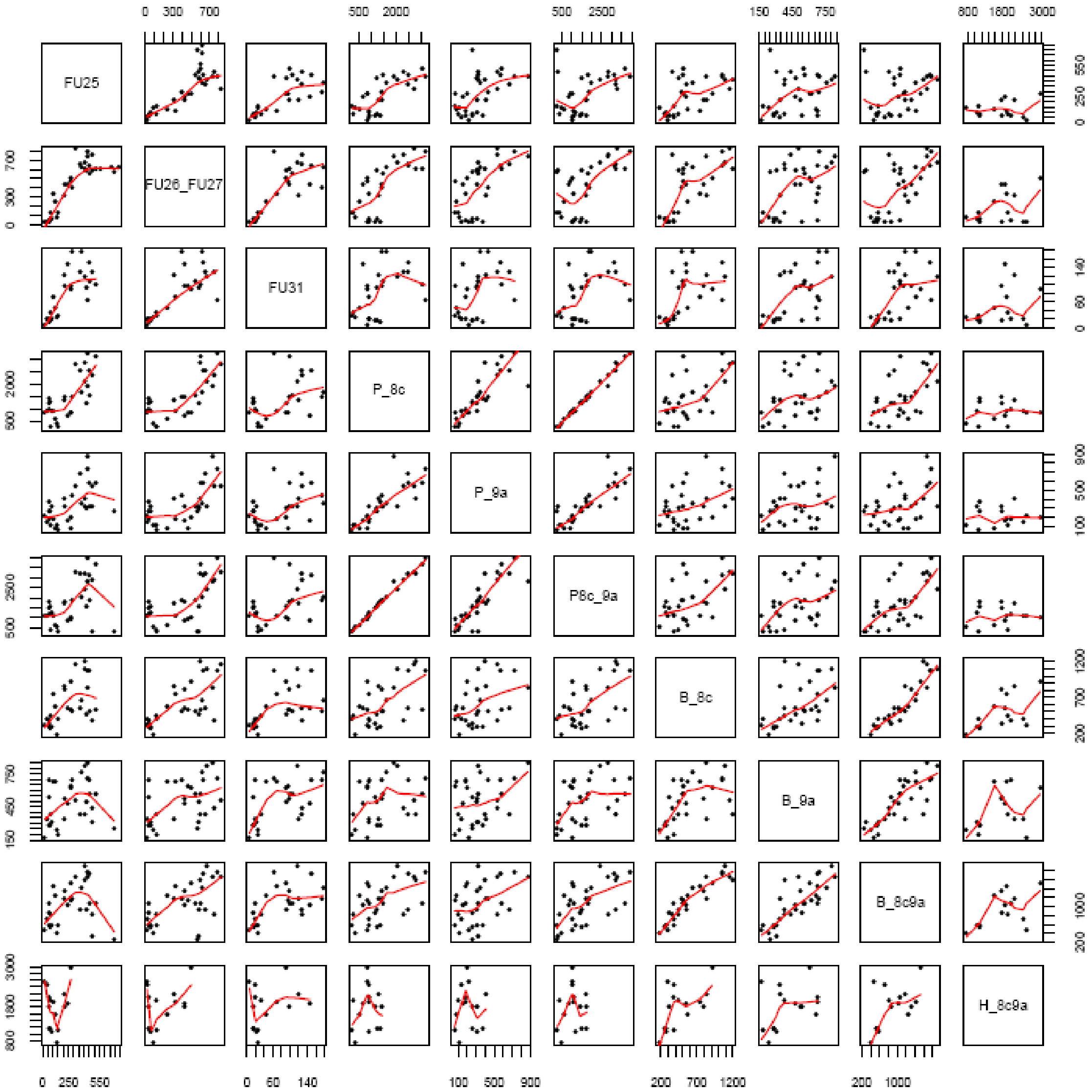


FIGURE 3: Scatterplots of landings of *Nephrops* and *L. piscatorius*, by the Spanish bottom trawl fleet operating in Div. VIIIc+IXaN together. Blue line represents least squares fit.

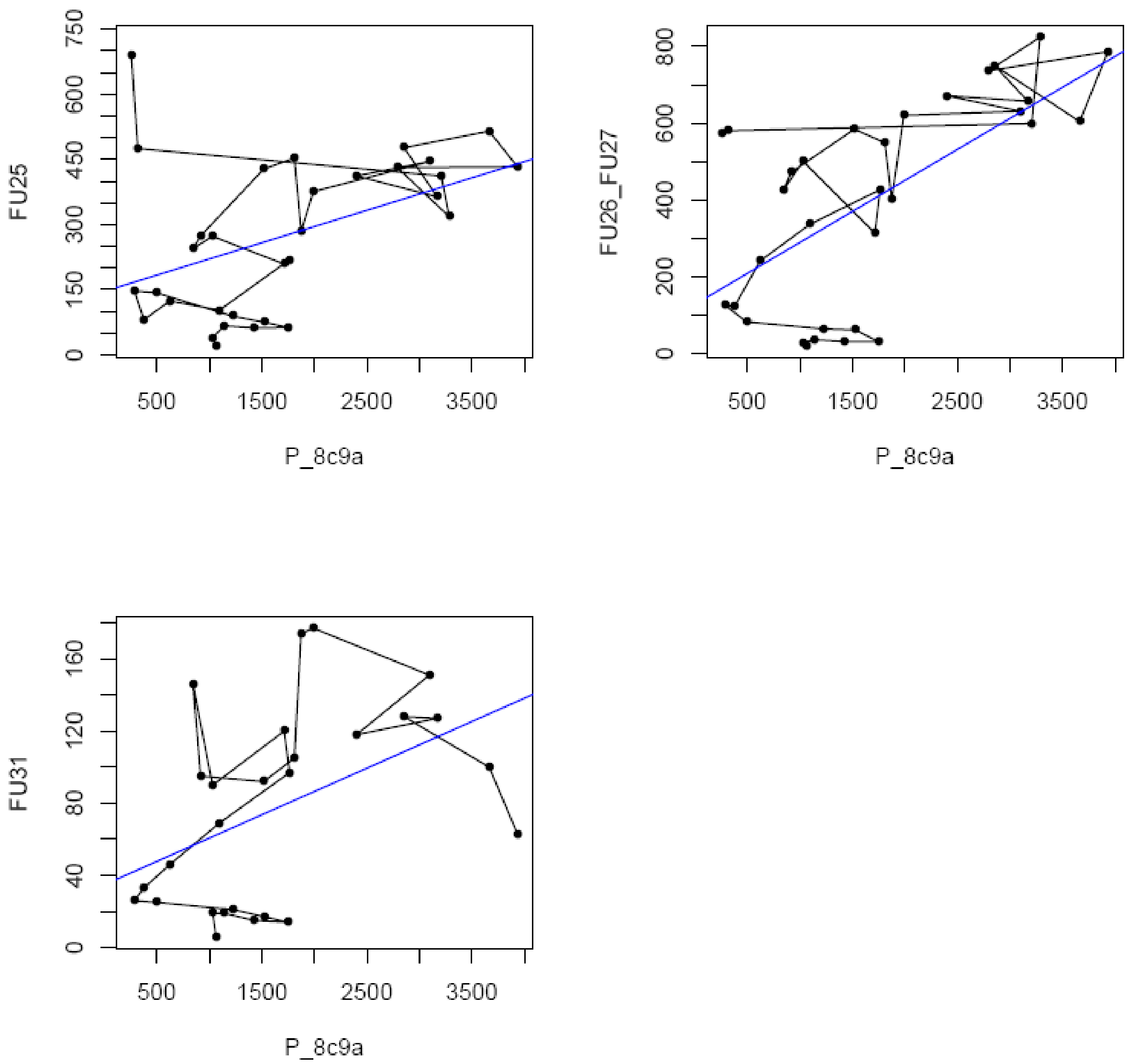


FIGURE 4: Scatterplots of landings of *Nephrops* and *L. budegassa*, by the Spanish bottom trawl fleet operating in Div. VIIIc+IXaN together. Blue line represents least squares fit.

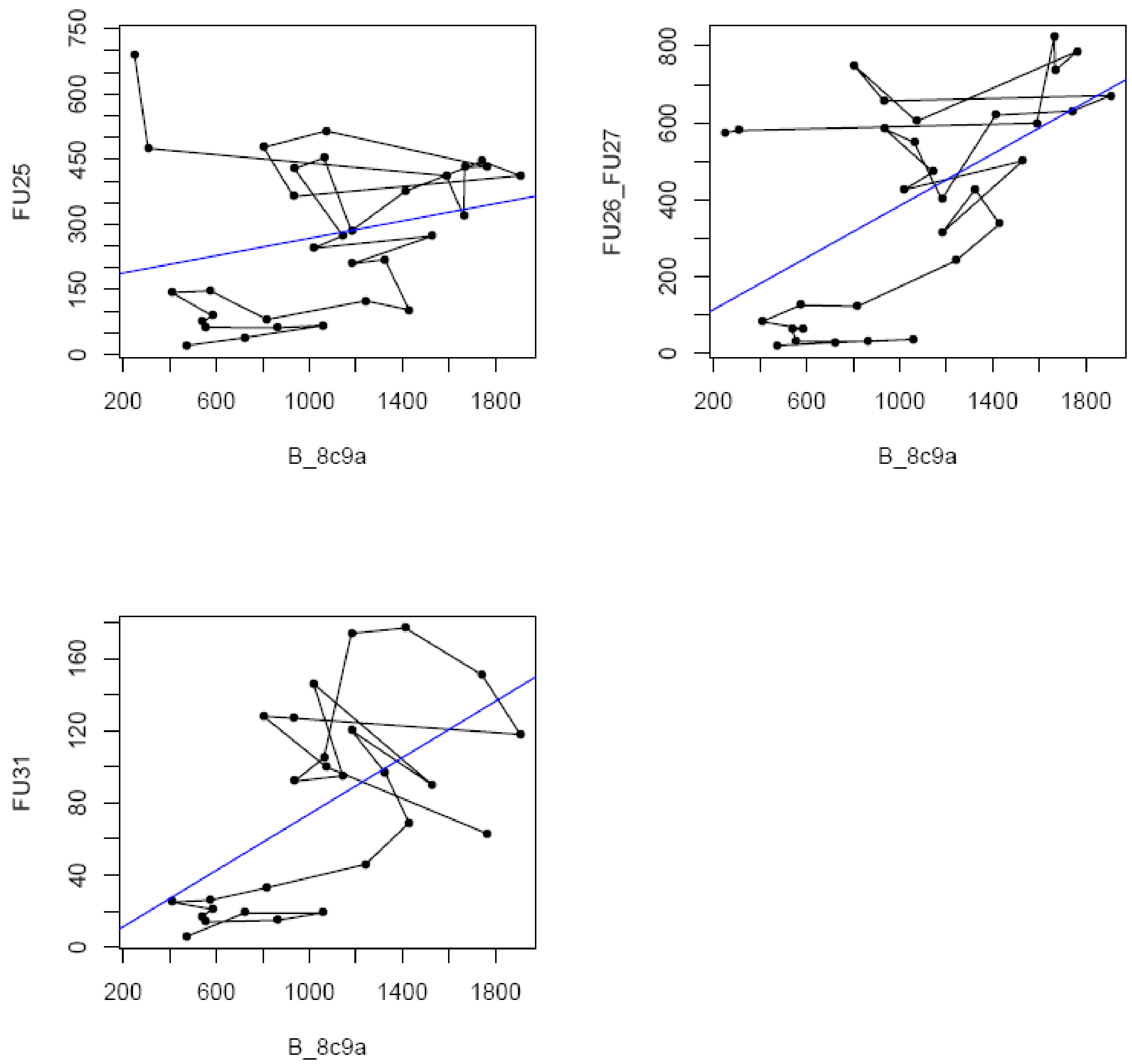


FIGURE 5: Scatterplots of landings of *Nephrops* and *L. piscatorius+L. budegassa*, by the Spanish bottom trawl fleet operating in Div. VIIIc+IXaN together. Blue line represents least squares fit.

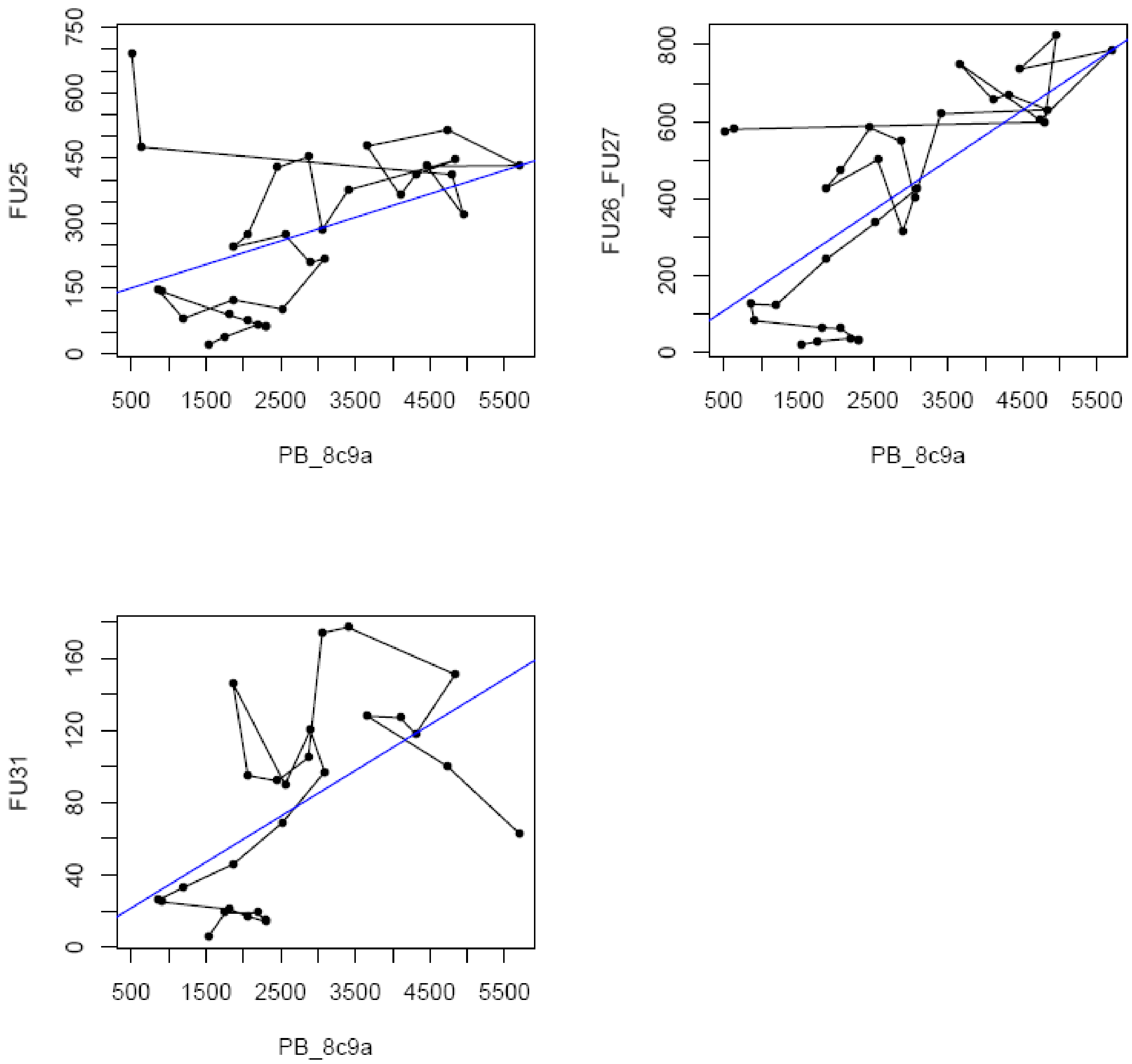


FIGURE 6: Estimated F trends for *Nephrops* (top), *L. piscatorius* (middle) and *L. budegassa* (bottom), by the Spanish bottom trawl fleet operating in Div. VIIIc, IXa (North) and VIIIc+IXaN together. Do not interpret values on vertical axes, only trends.

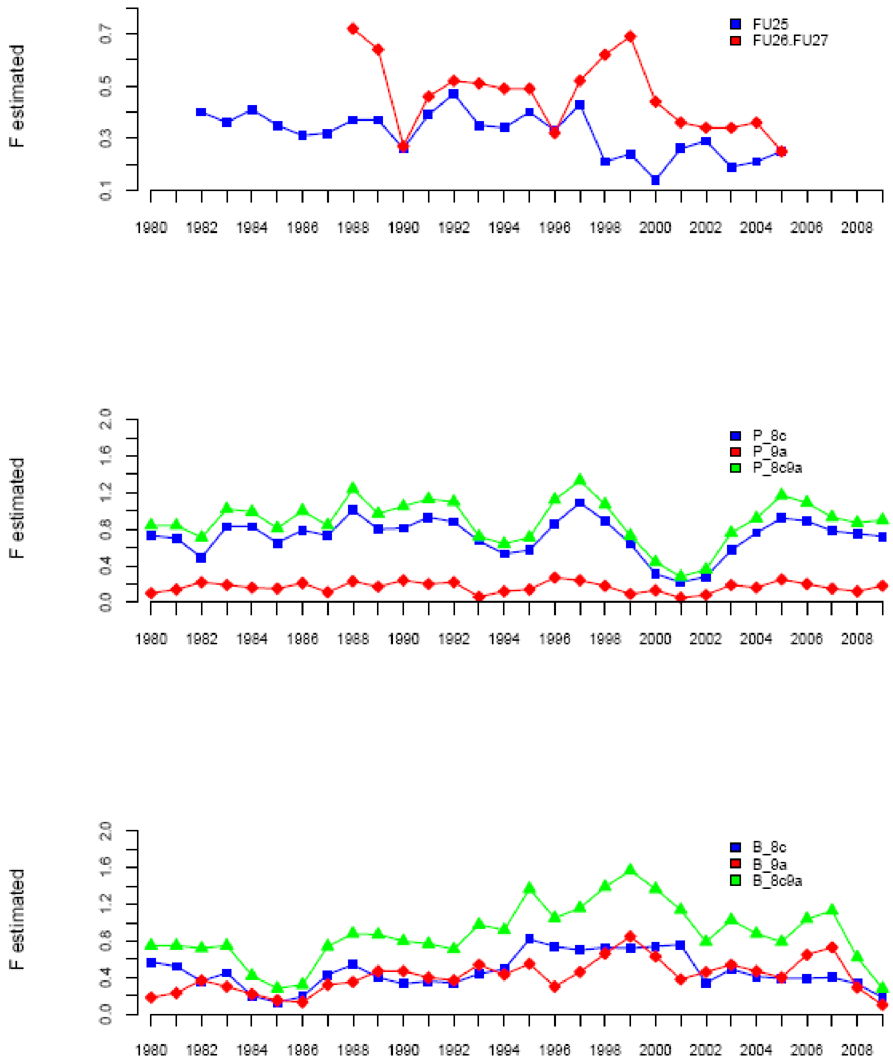


FIGURE 7: Scatterplots of estimated F for *Nephrops*, *L. piscatorius* and *L. budegassa*, corresponding to the Spanish bottom trawl fleet operating in Div. VIIIc, IXa (North) and VIIIc+IXaN together

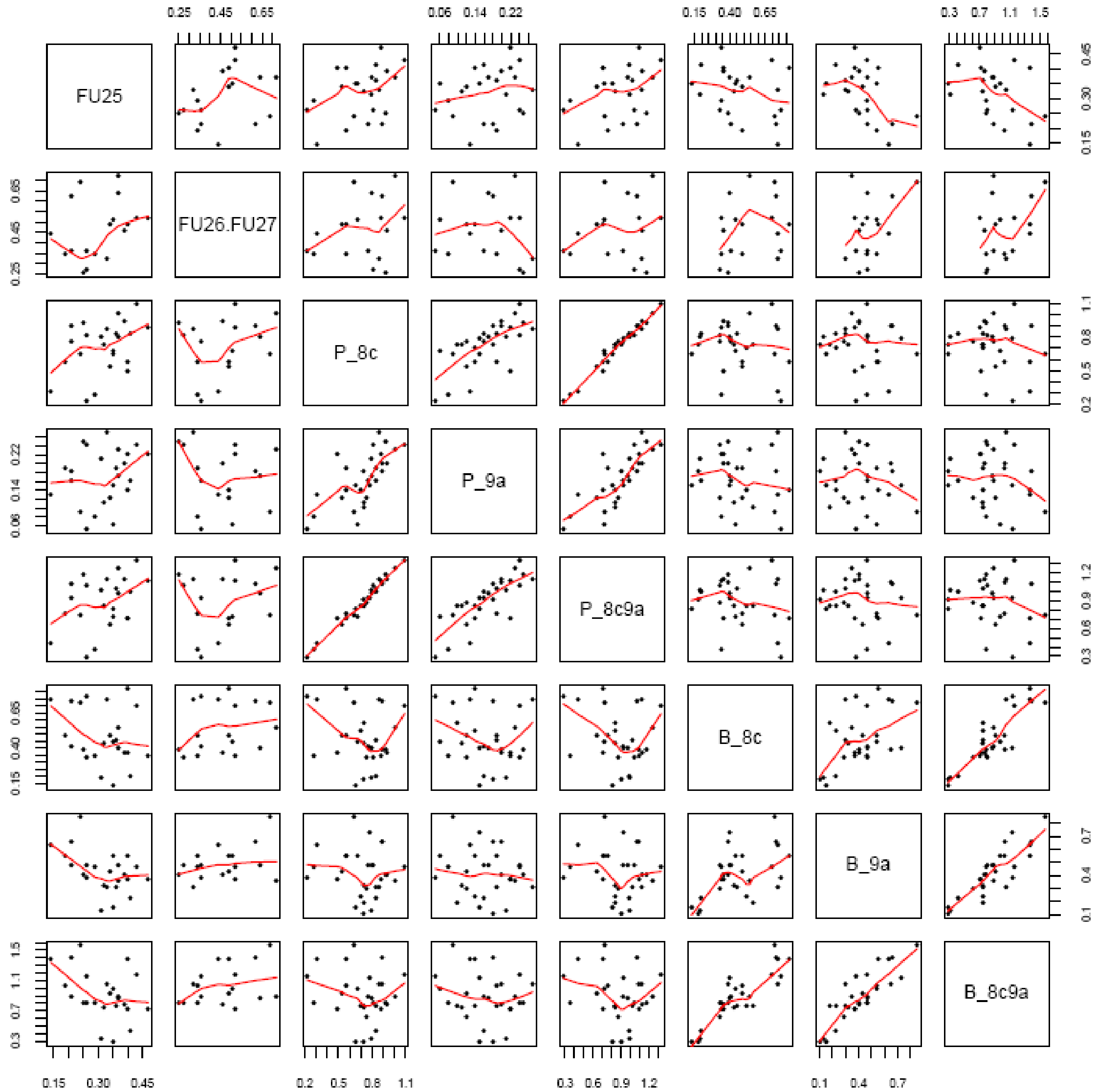
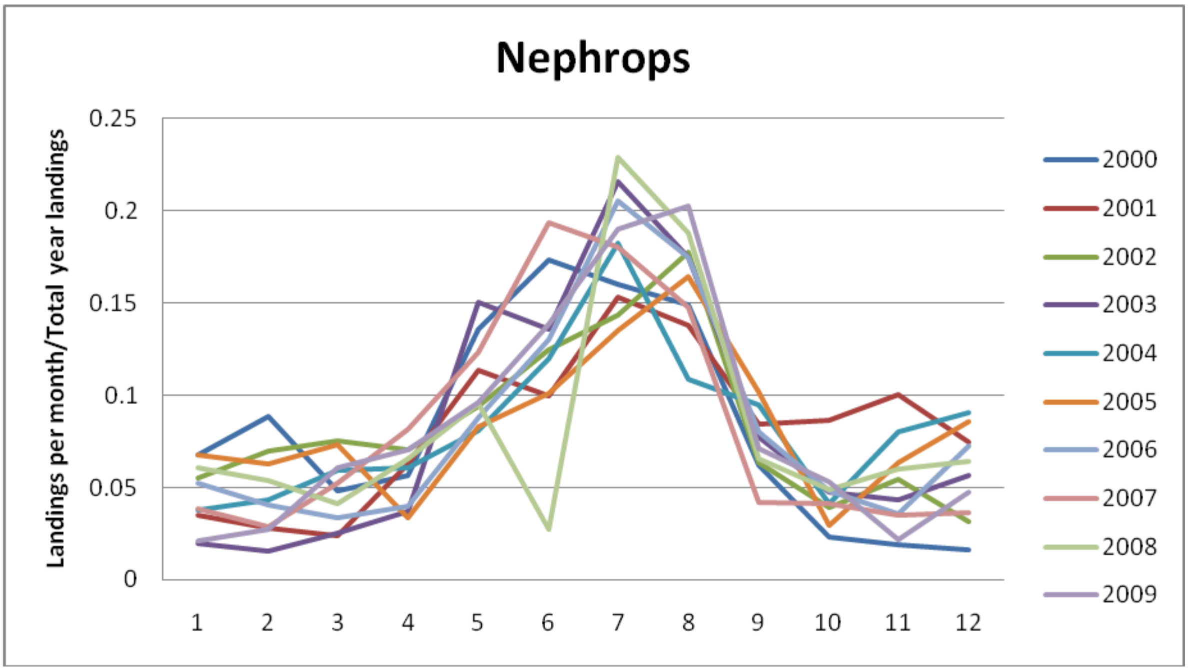


FIGURE 8: Monthly percentage of annual landings of the Spanish bottom trawl fleet, for *Nephrops* FUs 25, 26-27 and 31 combined.



ANNEX: LINEAR FITS CORRESPONDING TO FIGURES 3, 4 AND 5

> summary(lm(FU25~PB_8c9a))

```
Call:
lm(formula = FU25 ~ PB_8c9a)

Residuals:
    Min      1Q  Median      3Q     Max
-186.379 -114.150   -1.948   60.648  538.420

Coefficients:
            Estimate Std. Error t value Pr(>|t|)
(Intercept) 124.19445   64.12822   1.937   0.0623 .
PB_8c9a       0.05412    0.02082   2.599   0.0144 *
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 161.8 on 30 degrees of freedom
  (3 observations deleted due to missingness)
Multiple R-squared: 0.1838,     Adjusted R-squared: 0.1566
F-statistic: 6.755 on 1 and 30 DF,  p-value: 0.01436
```

> summary(lm(FU26_FU27~PB_8c9a))

```
Call:
lm(formula = FU26_FU27 ~ PB_8c9a)

Residuals:
   Min      1Q  Median     3Q     Max
-312.07  -85.77  -32.97  131.58  465.00

Coefficients:
            Estimate Std. Error t value Pr(>|t|)
(Intercept) 44.12913   79.18674   0.557    0.581
PB_8c9a      0.13018    0.02571   5.063 1.95e-05 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 199.8 on 30 degrees of freedom
  (3 observations deleted due to missingness)
Multiple R-squared: 0.4608,     Adjusted R-squared: 0.4428
F-statistic: 25.63 on 1 and 30 DF,  p-value: 1.950e-05
```

> summary(lm(FU31~PB_8c9a))

```
Call:
lm(formula = FU31 ~ PB_8c9a)

Residuals:
    Min      1Q  Median      3Q     Max 
-90.528 -34.217  -4.105  21.907  89.715 

Coefficients:
            Estimate Std. Error t value Pr(>|t|)   
(Intercept)  9.046074  21.306670   0.425  0.67479   
PB_8c9a      0.025370   0.007215   3.516  0.00169 **
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1 

Residual standard error: 44.95 on 25 degrees of freedom
  (8 observations deleted due to missingness)
Multiple R-squared: 0.3309,     Adjusted R-squared: 0.3042 
F-statistic: 12.37 on 1 and 25 DF,  p-value: 0.001694
```

> summary(lm(FU25~P_8c9a))

```
Call:
lm(formula = FU25 ~ P_8c9a)

Residuals:
    Min      1Q  Median      3Q     Max 
-213.88 -101.31  -12.97   77.54  524.51 

Coefficients:
            Estimate Std. Error t value Pr(>|t|)   
(Intercept) 146.21538   54.05627   2.705  0.01115 * 
P_8c9a        0.07471    0.02707   2.760  0.00976 **
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1 

Residual standard error: 159.9 on 30 degrees of freedom
  (3 observations deleted due to missingness)
Multiple R-squared: 0.2025,     Adjusted R-squared: 0.1759 
F-statistic: 7.617 on 1 and 30 DF,  p-value: 0.009763
```

> summary(lm(FU26_FU27~P_8c9a))

```
Call:
lm(formula = FU26_FU27 ~ P_8c9a)

Residuals:
    Min      1Q  Median      3Q     Max 
-378.53 -117.89   13.49  161.40  404.97 

Coefficients:
            Estimate Std. Error t value Pr(>|t|)    
(Intercept) 128.4122    70.6934   1.816   0.0793 .  
P_8c9a        0.1613     0.0354   4.557 8.12e-05 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1 

Residual standard error: 209.1 on 30 degrees of freedom
  (3 observations deleted due to missingness)
Multiple R-squared: 0.409,      Adjusted R-squared: 0.3893 
F-statistic: 20.76 on 1 and 30 DF,  p-value: 8.123e-05
```

> summary(lm(FU31~P_8c9a))

```
Call:
lm(formula = FU31 ~ P_8c9a)

Residuals:
    Min      1Q  Median      3Q     Max 
-73.493 -43.835   5.868  26.000  90.743 

Coefficients:
             Estimate Std. Error t value Pr(>|t|)  
(Intercept) 34.781393  18.582010   1.872   0.0730 .
P_8c9a       0.025868   0.009725   2.660   0.0134 *
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1 

Residual standard error: 48.51 on 25 degrees of freedom
  (8 observations deleted due to missingness)
Multiple R-squared: 0.2206,     Adjusted R-squared: 0.1894 
F-statistic: 7.076 on 1 and 25 DF,  p-value: 0.01344
```

> summary(lm(FU25~B_8c9a))

```
Call:
lm(formula = FU25 ~ B_8c9a)

Residuals:
    Min      1Q  Median      3Q     Max 
-207.76 -150.13  -20.48   98.00  497.09 

Coefficients:
             Estimate Std. Error t value Pr(>|t|)  
(Intercept) 168.16726   77.19050   2.179   0.0374 *
B_8c9a        0.09979    0.06723   1.484   0.1482  
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1 

Residual standard error: 172.8 on 30 degrees of freedom
  (3 observations deleted due to missingness)
Multiple R-squared: 0.0684,     Adjusted R-squared: 0.03735 
F-statistic: 2.203 on 1 and 30 DF,  p-value: 0.1482 
```

> summary(lm(FU26_FU27~B_8c9a))

```
Call:
lm(formula = FU26_FU27 ~ B_8c9a)

Residuals:
    Min      1Q  Median      3Q     Max 
-366.54 -181.03  -31.92  143.60  443.91 

Coefficients:
            Estimate Std. Error t value Pr(>|t|)    
(Intercept) 47.46436   98.82209   0.480 0.634497    
B_8c9a       0.33719    0.08608   3.917 0.000479 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1 

Residual standard error: 221.3 on 30 degrees of freedom
  (3 observations deleted due to missingness)
Multiple R-squared: 0.3384,     Adjusted R-squared: 0.3164 
F-statistic: 15.35 on 1 and 30 DF,  p-value: 0.0004789 
```

> summary(lm(FU31~B_8c9a))

```
Call:
lm(formula = FU31 ~ B_8c9a)

Residuals:
   Min     1Q Median     3Q    Max
-70.47 -26.70 -14.50  24.72  86.08

Coefficients:
            Estimate Std. Error t value Pr(>|t|)
(Intercept) -4.25753   23.72760  -0.179  0.85904
B_8c9a       0.07812    0.02116   3.692  0.00109 **
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 44.2 on 25 degrees of freedom
  (8 observations deleted due to missingness)
Multiple R-squared: 0.3528,     Adjusted R-squared: 0.3269
F-statistic: 13.63 on 1 and 25 DF,  p-value: 0.001088
```